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Research Article

From Tiny Hands to Steady Hands to Weary Hands: Age-Related Change Rates in Grip Strength Across the Lifespan

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Abstract

This study aimed to quantify the rate of change (kg/year) and percentage change (%) in grip strength across the lifespan (ages 3-85), stratified by gender and hand dominance. This was a cross-sectional observational study. Data were obtained from 3,901 noninstitutionalized U.S. residents aged 3 to 85 who had participated in the NIH Toolbox study. Grip strength was measured with a Jamar dynamometer and both the rate of change (kg/year) and percentage change (%) were calculated for the dominant and nondominant hands by gender. Results showed that grip strength change rates peaked early in life and then steadily declined with age. At age 14, males exhibited their highest annual gain (4.58 kg/year) and females peaked at age 11 (2.87 kg/year). After these peak ages, the change rate turned negative by early adulthood, marking the start of functional decline. By age 60, men were losing 0.35 kg of grip strength per year and women 0.30 kg per year. From ages 66 to 85, annual losses stabilized at approximately 0.35-0.37 kg for men and 0.27-0.28 kg for women. In relative terms, percentage loss accelerated after midlife: by age 50 males had lost 7.37% of their peak strength and females 3.13%. These percentage declines deepened to 22.96% in males and 25.23% in females by age 72 and further to 33.27% in males and 37.62% in females by age 85, illustrating a progressive, age-related decrease in muscle function. Knowing the reference values for the rate of grip strength decline during normal aging was essential for distinguishing healthy aging from early signs of muscle dysfunction. These values served as benchmarks to assess whether an individual's decline was within the expected range or indicated a higher risk of frailty, sarcopenia or other age-related conditions.

Keywords: Grip Strength; Healthy Aging; Muscle Strength; Physical Function; Frailty

Introduction

Physical function across the lifespan supports an individual's capacity for independent living and is a cornerstone of healthy aging. Adequate muscle strength, balance and mobility enables the performance of essential activities, thus reducing reliance on caregivers and healthcare services. Conversely, declines in physical function often mark the onset of frailty and sarcopenia, heightening the risk of falls, hospitalization and chronic disease. Monitoring functional biomarkers like grip strength offers a simple yet powerful window into one's aging trajectory, allowing for early interventions that preserve independence and quality of life.

Grip strength, measured by a dynamometer, is a simple, fast and effective functional biomarker in aging research. As a measure of the maximum voluntary force of the hand, it reflects the overall musculoskeletal health and physiological resilience [1,2]. Recognized as a hallmark of sarcopenia and frailty, weak grip strength has been linked with greater risks of hospital-associated disability, dementia, cardiovascular disease, mobility limitation and premature mortality [3-11]. Moreover, it predicts malnutrition disease severity in hospitalized COVID-19 patients and poorer post-surgical outcomes [12-14].

In both research and clinical settings, grip strength values have guided decision-making and risk stratification. Researchers in multiple countries have developed population-based reference norms for grip strength across the lifespan to help interpret individual test scores [15-31]. Clinically relevant thresholds Additionally, grip strength cut-offs (defined as grip strength <37 kg, <29 kg or <26 kg for men and <21 kg, <17 kg or <16 kg for women) have been used to identify those at risk for mobility limitation have been used to predict mobility limitation, frailty risk and higher hazard of adverse health outcomes [3,9,11,32].

Research has further explored the relationship between grip strength decline and various health conditions. Buchman, et al., 7 reported that each 1-lb decrease in baseline grip strength was linked to a 1.5% higher risk of Alzheimer's disease. Similarly, Kuo, et al., found that a 5-kg increase in absolute grip strength was associated with a lower risk of all-cause dementia [33,34]. Liu, et al., (2019) demonstrated that every 5-kg reduction in grip strength correlated with decreased survival rates in older patients with hematologic malignancies [35]. Perna, et al., estimated that a modest (~17%) increase in grip strength could reduce the risk of metabolic syndrome by 14-24% [24]. These findings underscore the critical role of muscle strength in aging, reinforcing its importance for disease prevention and longevity.

Despite the well-documented importance of grip strength as a functional biomarker, few studies have systematically quantified its rate of decline across the lifespan, leaving this aspect insufficiently characterized [31,36-39]. In a cohort of adult with chronic liver disease (median age ~65 years), Endo reported annual grip strength declines of -2.93% in men and -1.71% in women [36]. Among older adults (ages 65-90) in the survey of health, ageing and retirement in Europe, Kröger, observed a linear decline of -0.70 kg/year in men and -0.42 kg/year in women [37]. Similarly, the Newcastle 85+ Study (ages >85), Granic, found a 5-year reduction of -5.27 kg in men and -3.14 kg in women, with subsequent regression analysis estimating an annual decline of -1.13 kg/year in men and -0.31 kg/year in women [38]. These findings underscore the need for a more comprehensive analysis that spans a broader age range and accounts for different rates of decline at various life stages.

Hence, this study aimed to provide a population-based analysis of age- related grip strength change from childhood to late adulthood. Specifically, the objectives were: (1) to quantify the rate of change (kg/year) in grip strength across ages 3-85 and (2) to determine the percentage decline (%) relative to peak grip strength, stratified by gender and hand dominance.

Ethical Statement

The project did not meet the definition of human subject research under the purview of the IRB according to federal regulations and therefore, was exempt.

Methods

Data Source - NIH Toolbox Study

Funded by the National Institutes of Health, the NIH Toolbox project sought to develop a concise yet comprehensive battery of emotional, cognitive, sensory and motor assessments that could be applied uniformly across clinical and research settings to track functional health trajectories. During its 2011 normative phase, grip strength was measured in 3- to 85-year-old, community-dwelling, noninstitutionalized participants who were able to follow instructions and provide informed consent (or assent with parental permission). Data were gathered at ten primarily urban and suburban sites-Atlanta; Oak Brook (Chicago); Cincinnati; Columbus; Dallas; Los Angeles; Minneapolis; Philadelphia; Phoenix and St. Louis-using an age-, gender- and language-stratified sampling strategy (English and Spanish). The sampling methodology has been previously described [40]. Additionally, normative reference values derived from this dataset have been published, providing a valuable resource for researchers and clinicians [29,41].

Grip Strength Measurements

Grip strength was assessed with a digital Jamar® dynamometer while participants sat in a standardized posture to maximize consistency. Given the time constraints of the NIH Toolbox norming study, each hand first completed one submaximal practice trial, followed by a 30-second rest before a single 3-4-second maximal effort. Examiners encouraged maximal voluntary contraction by chanting "Harder, harder, harder," and recorded the peak force in pounds, which was subsequently converted to kilograms. This procedure closely follows the clinical guidelines of the American Society of Hand Therapists (ASHT).

Statistical Analysis

All data were subjected to statistical analysis using IBM SPSS Statistics Version 29 (Armonk, NY: IBM Corp.) and Google Colaboratory. Data preprocessing included the identification and removal of potential outliers to enhance the robustness of the subsequent analyses. Specifically, participants were excluded if their grip strength values exceeded 1.5 times the Interquartile Range (IQR) for their respective sex and age group or if the absolute difference between dominant and nondominant hand grip strength exceeded 25%, following previously established methodological criteria [29].

Grip strength trajectories were modeled separately by sex (male, female) and hand dominance (dominant, nondominant hand) to account for potential biological and functional differences. Locally Weighted Scatterplot Smoothing (LOESS) was applied to mitigate data fluctuations while preserving the underlying trend [37]. The smoothed trajectories were plotted alongside raw observations to verify that the fitted trend accurately reflected the empirical data without introducing systematic bias.

The annualized rate of change in grip strength (kg/year) was estimated as the year-over-year difference in mean grip strength across consecutive age groups. The percentage change (%) in grip strength relative to peak strength was calculated as: Percentage change = 100 x (grip strength - reference grip strength)/ (reference grip strength), where the reference grip strength was defined as the mean grip strength observed between ages 19 and 20, representing the approximate age of peak muscular strength. The percentage change metric provided a normalized measure of decline, enabling comparisons across different age groups and facilitating the identification of age-related inflection points in strength deterioration. These statistical approaches ensured a robust analysis of grip strength trajectories across the lifespan while minimizing bias and maximizing interpretability in both absolute (kg/year) and relative (%) terms.

Results

Sample

Of the 4,859 initial records, one participant was excluded due to missing age, 121 for extreme outliers (>1.5 IQR) and 836 for excessive between-side grip strength differences (>25%), resulting in a final sample of 3,901 participants aged 3-85 years. The sample was 44.7% male, 55.3% female and 92.4% right-hand dominant. Racial composition included 75.8% non-Hispanic White, 14.5% Black/African American, 3.1% American Indian/Alaska Native and 1.7% Asian. Table 1 provides detailed demographics.

Grip Strength Trajectories

Fig.1 illustrates the observed and smoothed trajectories of grip strength (kg) across different ages. Overall, grip strength increased during childhood, peaked around ages 19-37 and then began a gradual decline.

Rate of Change

Table 2 summarizes the rate of change (kg/year) and percentage change (%) in handgrip strength for females, while Table 3 presents the corresponding data for males. Fig. 2 visually represents the rate of change and percentage change in grip strength.

Dominant Hand

In females, grip strength increased rapidly from age 4 (1.93 kg/yr) to a peak rate of change at age 11 (2.87 kg/yr), followed by a decline through adolescence and young adulthood-dropping to 1.17 kg/yr by age 15, 0.63 kg/yr at age 16 and 0.21 kg/yr by age 18 and nearing zero at age 19. After about age 39, the rate of change gradually declined from -0.01 kg/yr to -0.30 kg/yr by age 60, with loss accelerating after age 50 (-0.26 to -0.31 kg/yr) and stabilizing around -0.27 to -0.28 kg/yr from ages 66-85, indicating a steady age-related decline in muscle strength (Table 2).

In males, grip strength increased rapidly from age 4 (1.96 kg/yr) to a peak rate of change at age 14 (4.58 kg/yr), followed by a decline through adolescence and young adulthood-dropping to 3.46 kg/yr by age 16, 2.19 kg/yr at age 18 and 0.14 kg/yr by age 19 and nearing zero around age 20. After age 30, the grip strength gradually declined from 0.05 kg/yr to -0.35 kg/yr by age 60, with loss accelerating after age 50 (-0.24 to -0.35 kg/yr) and stabilizing around -0.36 to -0.37 kg/yr from ages 66-85, indicating a consistent age-related decline in muscle strength (Table 3).

Nondominant Hand

In females, grip strength followed a similar trajectory: it increased from age 4 (1.82 kg/yr) to a peak at age 12 (2.72 kg/yr), then declined through adolescence to 1.27 kg/yr at age 14, 0.58 kg/yr at age 16 and neared zero around age 18 (-0.06 kg/yr). After about age 39, grip strength loss continued, declining to -0.28 kg/yr by age 60, with an accelerated drop after age 50 (-0.22 to -0.28 kg/yr) before stabilizing at -0.24 to -0.25 kg/yr from ages 66-85 (Table 2).

In males, nondominant hand grip strength increased rapidly from age 4 (2.00 kg/yr) to a peak at age 14 (4.24 kg/yr), then declined through adolescence and young adulthood-reaching 3.38 kg/yr at age 16, 1.82 kg/yr at age 18 and 0.48 kg/yr at age 19-before nearing zero around age 20. After about age 30, the change rate dropped to -0.36 kg/yr by age 60, with loss accelerating after age 50 (-0.21 to -0.36 kg/yr) and stabilizing at -0.36 to -0.38 kg/yr from ages 66-85 (Table 3).

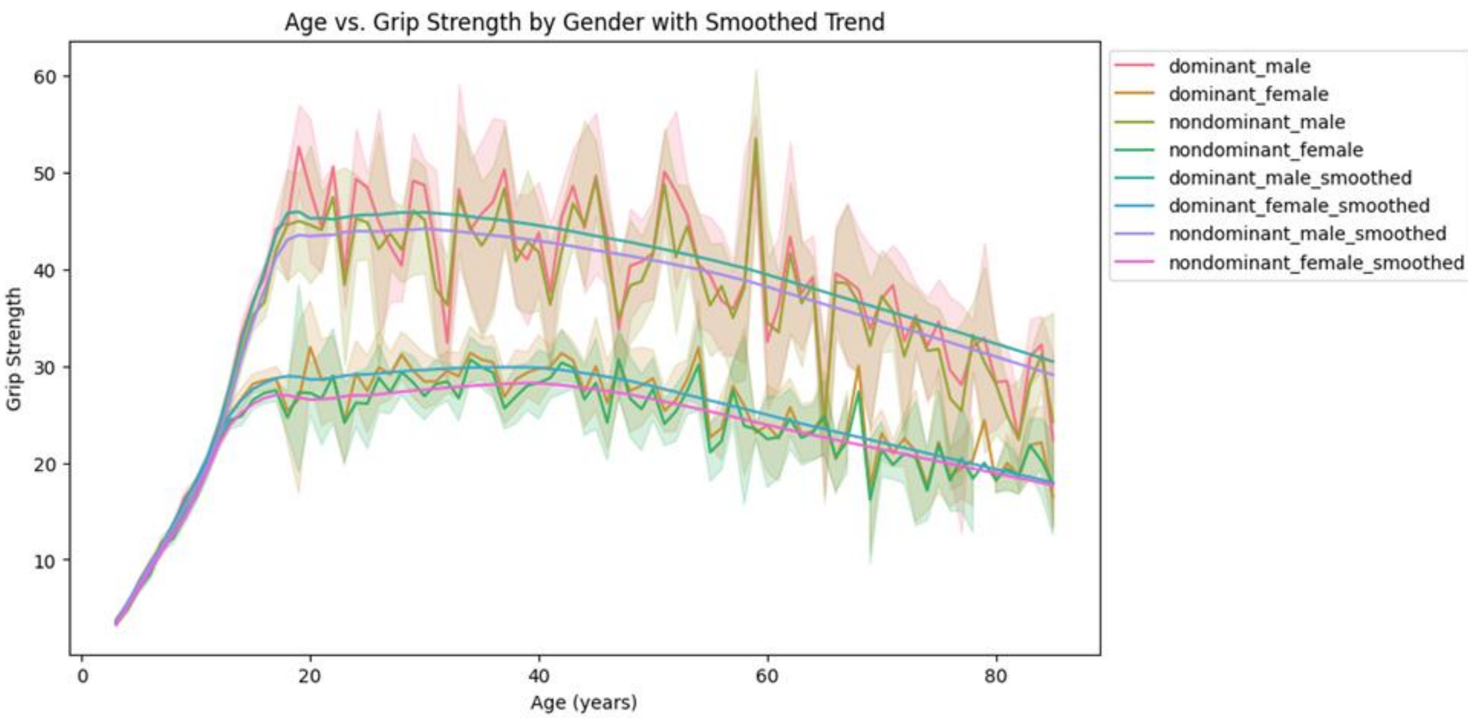

Figure 1: Observed and smoothed trajectories of grip strength (kg) from ages 3 to 85 years.

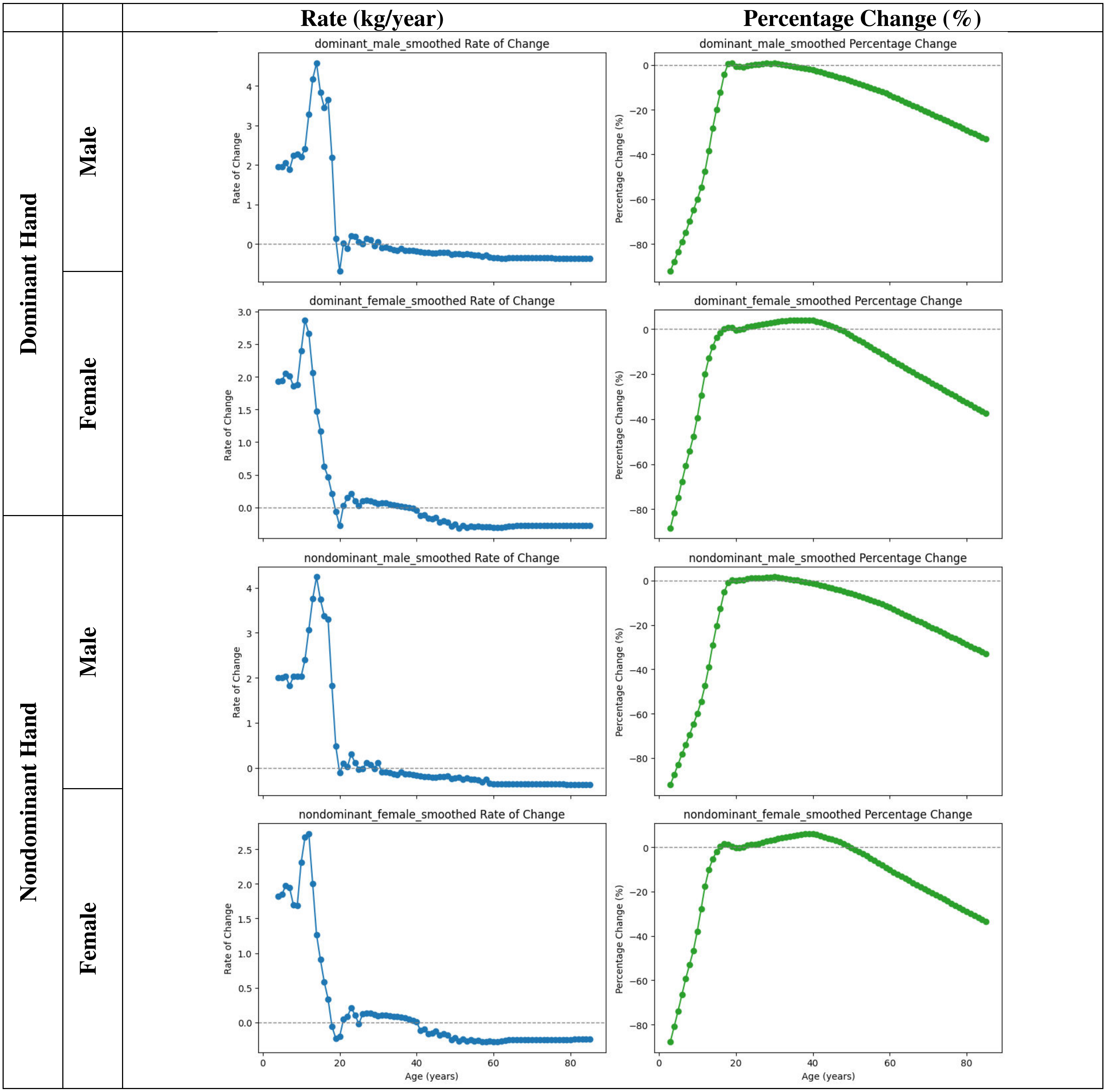

Figure 2: Rate (kg/year) and percentage change (%) in handgrip strength (kg) across the lifespan (3 to 85 years old).

Variables		
Age		
Mean (SD) (minimum, maximum)	21.75 (20.17)	(3, 85)
Gender	**Frequency**	**Percent**
Male	1,743	44.7
Female	2,158	55.3

Handedness		
Right-handed	3,604	92.4
Left-handed	297	7.6
Body Mass Index (BMI)		
< 18.5 Underweight	1063	27.2
18.5 – 24.9 Normal weight	1339	34.3
25.0 – 29.9 Overweight	575	14.7
> 30 Obesity	474	12.2
Missing	450	11.5
Race		
White	2,958	75.8
Black or African American	565	14.5
American Indian or Alaska Native	119	3.1
Native Hawaiian or Other Pacific Islander	5	0.1
Asian	68	1.7
Missing	186	4.8
Age group		
3 yr	124	3.2
4 yr	147	3.8
5 yr	148	3.8
6 yr	182	4.7
7 yr	207	5.3
8 yr	177	4.5
9 yr	191	4.9
10 yr	201	5.2
11 yr	181	4.6
12 yr	192	4.9
13 yr	190	4.9
14 yr	206	5.3
15 yr	184	4.7
16 yr	181	4.6
17 yr	197	5.0
18-29 yr	223	5.7
30-39 yr	252	6.5
40-49 yr	211	5.4
50-59 yr	165	4.2
60-69 yr	140	3.6
70-85 yr	202	5.2
Total	3,901	100.0

Table 1: Demographic characteristics of the sample.

Female		**Dominant**			**Nondominant**		
Age	**N**	**Grip (kg)**	**Rate of Change (kg/year)**	**Percentage Change (%)**	**Grip (kg)**	**Rate of Change (kg/year)**	**Percentage Change (%)**
3	62	3.35		-88.35	3.26		-87.75

4	83	5.27	1.93	-81.66	5.08	1.82	-80.91
5	83	7.22	1.94	-74.90	6.93	1.85	-73.97
6	92	9.27	2.05	-67.76	8.90	1.97	-66.57
7	103	11.28	2.01	-60.76	10.85	1.94	-59.28
8	82	13.14	1.86	-54.30	12.54	1.69	-52.92
9	93	15.02	1.88	-47.75	14.23	1.69	-46.57
10	102	17.42	2.39	-39.42	16.54	2.31	-37.91
11	91	20.28	2.87	-29.45	19.21	2.67	-27.89
12	106	22.95	2.66	-20.19	21.93	2.72	-17.67
13	89	25.00	2.06	-13.03	23.93	2.00	-10.16
14	110	26.48	1.47	-7.92	25.20	1.27	-5.40
15	92	27.64	1.17	-3.85	26.11	0.91	-2.00
16	92	28.27	0.63	-1.67	26.69	0.58	0.20
17	99	28.74	0.47	-0.05	27.03	0.34	1.46
18	4	28.95	0.21	0.68	26.97	-0.06	1.25
19	3	28.89	-0.06	0.48	26.74	-0.23	0.38
20	6	28.61	-0.28	-0.48	26.53	-0.20	-0.38
21	10	28.64	0.03	-0.39	26.58	0.04	-0.23
22	7	28.79	0.15	0.13	26.66	0.08	0.08
23	10	29.00	0.21	0.88	26.87	0.21	0.88
24	17	29.11	0.10	1.23	26.98	0.11	1.29
25	13	29.14	0.03	1.35	26.96	-0.02	1.20
26	17	29.24	0.10	1.70	27.08	0.12	1.67
27	15	29.35	0.11	2.07	27.21	0.13	2.16
28	28	29.45	0.10	2.43	27.34	0.13	2.64
29	29	29.54	0.09	2.73	27.46	0.12	3.08
30	25	29.60	0.06	2.94	27.55	0.10	3.44
31	24	29.66	0.07	3.17	27.66	0.10	3.82
32	24	29.74	0.08	3.43	27.76	0.11	4.23
33	17	29.79	0.05	3.61	27.85	0.09	4.57
34	18	29.83	0.04	3.75	27.94	0.09	4.90
35	19	29.86	0.03	3.85	28.02	0.08	5.21
36	17	29.88	0.02	3.91	28.10	0.07	5.48
37	18	29.88	0.01	3.94	28.16	0.06	5.72
38	19	29.88	0.00	3.94	28.21	0.05	5.92
39	17	29.87	-0.01	3.89	28.24	0.03	6.04
40	19	29.83	-0.04	3.76	28.25	0.00	6.05
41	23	29.71	-0.13	3.32	28.13	-0.11	5.62
42	14	29.60	-0.11	2.93	28.04	-0.09	5.27
43	16	29.43	-0.16	2.36	27.88	-0.16	4.66
44	15	29.25	-0.18	1.75	27.72	-0.16	4.07
45	11	29.10	-0.15	1.22	27.60	-0.12	3.60
46	8	28.88	-0.22	0.45	27.41	-0.18	2.91
47	11	28.68	-0.20	-0.24	27.25	-0.16	2.30

48	10	28.46	-0.22	-1.01	27.06	-0.19	1.60
49	11	28.17	-0.29	-2.01	26.81	-0.25	0.66
50	13	27.91	-0.26	-2.91	26.59	-0.22	-0.17
51	13	27.60	-0.31	-4.00	26.32	-0.27	-1.17
52	13	27.32	-0.28	-4.96	26.09	-0.24	-2.06
53	15	27.02	-0.31	-6.04	25.82	-0.27	-3.06
54	11	26.73	-0.28	-7.02	25.57	-0.25	-4.00
55	2	26.44	-0.30	-8.05	25.30	-0.27	-5.02
56	11	26.16	-0.28	-9.03	25.04	-0.26	-6.00
57	6	25.86	-0.29	-10.05	24.76	-0.28	-7.03
58	6	25.56	-0.30	-11.09	24.48	-0.28	-8.08
59	3	25.27	-0.30	-12.12	24.21	-0.27	-9.11
60	11	24.96	-0.30	-13.17	23.93	-0.28	-10.15
61	10	24.66	-0.31	-14.24	23.65	-0.28	-11.20
62	10	24.35	-0.31	-15.30	23.38	-0.27	-12.22
63	15	24.06	-0.29	-16.32	23.12	-0.26	-13.20
64	11	23.77	-0.29	-17.31	22.87	-0.25	-14.15
65	8	23.49	-0.28	-18.29	22.62	-0.25	-15.08
66	5	23.21	-0.28	-19.26	22.37	-0.25	-16.00
67	6	22.94	-0.28	-20.23	22.13	-0.25	-16.93
68	1	22.66	-0.28	-21.20	21.88	-0.25	-17.85
69	6	22.38	-0.28	-22.16	21.63	-0.25	-18.78
70	12	22.10	-0.28	-23.13	21.39	-0.25	-19.71
71	9	21.82	-0.28	-24.09	21.14	-0.25	-20.64
72	9	21.55	-0.28	-25.06	20.89	-0.25	-21.56
73	7	21.27	-0.28	-26.02	20.64	-0.25	-22.49
74	5	20.99	-0.28	-26.98	20.40	-0.25	-23.43
75	5	20.72	-0.28	-27.94	20.15	-0.25	-24.36
76	7	20.44	-0.28	-28.90	19.90	-0.25	-25.29
77	2	20.17	-0.28	-29.86	19.65	-0.25	-26.21
78	4	19.89	-0.28	-30.82	19.41	-0.25	-27.14
79	1	19.61	-0.28	-31.78	19.16	-0.25	-28.07
80	11	19.34	-0.27	-32.74	18.91	-0.25	-28.99
81	11	19.07	-0.27	-33.69	18.67	-0.25	-29.91
82	10	18.79	-0.27	-34.64	18.42	-0.24	-30.83
83	7	18.52	-0.27	-35.59	18.18	-0.24	-31.75
84	6	18.25	-0.27	-36.53	17.94	-0.24	-32.66
85	2	17.98	-0.27	-37.48	17.70	-0.24	-33.57

Rate of change (kg/year) = change in grip strength (in kg) across consecutive years.
Percentage change = 100 x (grip strength - reference)/(reference), where the reference grip strength was defined as the mean grip strength observed between ages 19 and 20.

Table 2: Summary of the rate (kg/year) and percentage change (%) in handgrip strength (kg) among females aged 3 to 85 years.

Female		Dominant			Nondominant		
Age	N	Grip (kg)	Rate of Change (kg/year)	Percentage Change (%)	Grip (kg)	Rate of Change (kg/year)	Percentage Change (%)
3	62	3.62		-92.05	3.42		-92.13
4	64	5.58	1.96	-87.76	5.42	2.00	-87.54
5	65	7.54	1.96	-83.46	7.42	2.00	-82.94
6	90	9.60	2.06	-78.94	9.45	2.03	-78.27
7	104	11.49	1.89	-74.81	11.27	1.82	-74.08
8	95	13.73	2.24	-69.89	13.30	2.03	-69.42
9	98	16.01	2.28	-64.89	15.32	2.03	-64.76
10	99	18.21	2.20	-60.06	17.35	2.03	-60.09
11	90	20.62	2.41	-54.78	19.75	2.40	-54.57
12	86	23.91	3.28	-47.57	22.82	3.07	-47.51
13	101	28.08	4.17	-38.42	26.57	3.75	-38.88
14	96	32.66	4.58	-28.38	30.81	4.24	-29.13
15	92	36.50	3.85	-19.94	34.55	3.74	-20.53
16	89	39.96	3.46	-12.36	37.93	3.38	-12.75
17	98	43.61	3.65	-4.35	41.23	3.30	-5.17
18	8	45.80	2.19	0.46	43.05	1.82	-0.98
19	2	45.94	0.14	0.75	43.53	0.48	0.13
20	4	45.25	-0.69	-0.75	43.42	-0.11	-0.13
21	6	45.28	0.03	-0.69	43.52	0.10	0.10
22	2	45.16	-0.12	-0.95	43.54	0.02	0.15
23	3	45.37	0.21	-0.49	43.84	0.30	0.84
24	11	45.56	0.19	-0.08	43.96	0.11	1.10
25	5	45.62	0.06	0.06	43.92	-0.03	1.02
26	4	45.63	0.01	0.08	43.91	-0.02	0.99
27	5	45.77	0.14	0.39	44.02	0.12	1.26
28	4	45.87	0.10	0.61	44.10	0.07	1.42
29	10	45.83	-0.04	0.51	44.08	-0.02	1.38
30	2	45.88	0.05	0.63	44.19	0.11	1.64
31	5	45.79	-0.09	0.42	44.10	-0.10	1.42
32	4	45.70	-0.09	0.23	44.00	-0.09	1.21
33	4	45.60	-0.10	0.00	43.90	-0.11	0.96
34	4	45.46	-0.14	-0.31	43.76	-0.13	0.65
35	8	45.29	-0.16	-0.66	43.62	-0.15	0.32
36	5	45.19	-0.11	-0.90	43.52	-0.10	0.09
37	6	45.03	-0.16	-1.24	43.38	-0.14	-0.22
38	8	44.87	-0.16	-1.58	43.25	-0.14	-0.54
39	8	44.71	-0.17	-1.95	43.10	-0.15	-0.88
40	11	44.53	-0.18	-2.35	42.94	-0.16	-1.25
41	9	44.33	-0.20	-2.78	42.76	-0.18	-1.65
42	8	44.12	-0.21	-3.24	42.57	-0.19	-2.09

43	12	43.90	-0.22	-3.72	42.37	-0.20	-2.55
44	3	43.67	-0.23	-4.22	42.17	-0.21	-3.02
45	3	43.44	-0.23	-4.73	41.96	-0.21	-3.50
46	8	43.23	-0.21	-5.19	41.77	-0.19	-3.94
47	6	43.01	-0.22	-5.67	41.57	-0.20	-4.40
48	6	42.80	-0.21	-6.12	41.38	-0.19	-4.82
49	7	42.55	-0.26	-6.69	41.15	-0.23	-5.36
50	9	42.30	-0.24	-7.22	40.93	-0.22	-5.87
51	9	42.06	-0.24	-7.75	40.72	-0.21	-6.36
52	5	41.79	-0.27	-8.34	40.46	-0.26	-6.94
53	11	41.54	-0.25	-8.90	40.23	-0.23	-7.46
54	14	41.27	-0.27	-9.49	39.98	-0.25	-8.04
55	11	41.00	-0.27	-10.09	39.72	-0.26	-8.64
56	4	40.72	-0.28	-10.70	39.46	-0.27	-9.25
57	3	40.41	-0.31	-11.38	39.14	-0.31	-9.98
58	4	40.13	-0.27	-11.98	38.89	-0.26	-10.56
59	2	39.80	-0.34	-12.72	38.54	-0.34	-11.36
60	4	39.45	-0.35	-13.49	38.19	-0.36	-12.18
61	9	39.09	-0.36	-14.27	37.82	-0.36	-13.01
62	5	38.73	-0.36	-15.05	37.46	-0.36	-13.84
63	6	38.38	-0.36	-15.83	37.10	-0.36	-14.67
64	8	38.02	-0.36	-16.61	36.74	-0.36	-15.49
65	2	37.66	-0.36	-17.40	36.38	-0.36	-16.32
66	8	37.31	-0.36	-18.17	36.03	-0.36	-17.14
67	4	36.95	-0.35	-18.95	35.67	-0.36	-17.96
68	6	36.60	-0.35	-19.73	35.31	-0.36	-18.78
69	5	36.25	-0.35	-20.51	34.96	-0.36	-19.60
70	10	35.89	-0.35	-21.28	34.60	-0.36	-20.42
71	6	35.54	-0.35	-22.06	34.24	-0.36	-21.25
72	7	35.18	-0.35	-22.84	33.88	-0.36	-22.07
73	6	34.83	-0.35	-23.62	33.53	-0.36	-22.89
74	8	34.47	-0.36	-24.40	33.17	-0.36	-23.72
75	5	34.12	-0.36	-25.18	32.81	-0.36	-24.55
76	4	33.76	-0.36	-25.96	32.44	-0.36	-25.38
77	3	33.40	-0.36	-26.75	32.08	-0.36	-26.22
78	5	33.04	-0.36	-27.54	31.71	-0.37	-27.06
79	4	32.68	-0.36	-28.33	31.35	-0.37	-27.90
80	12	32.32	-0.36	-29.13	30.98	-0.37	-28.75
81	6	31.95	-0.36	-29.93	30.61	-0.37	-29.61
82	5	31.58	-0.37	-30.73	30.23	-0.37	-30.47
83	4	31.22	-0.37	-31.54	29.86	-0.38	-31.33
84	5	30.85	-0.37	-32.35	29.48	-0.38	-32.20

85	4	30.47	-0.37	-33.17	29.10	-0.38	-33.07
Rate of change (kg/year) = change in grip strength (in kg) across consecutive years. Percentage change = 100 x (grip strength - reference)/(reference), where the reference grip strength was defined as the mean grip strength observed between ages 19 and 20.							

Table 3: Summary of the rate (kg/year) and percentage change (%) in handgrip strength (kg) among males aged 3 to 85 years.

Percentage Change

Dominant Hand

In females, grip strength in early childhood was substantially lower than the peak levels around ages 19 and 20, with deficits ranging from -88.35% at age 3 to -39.42% at age 10. Adolescence (ages 11-17) marked a rapid increase in strength, which improved from -29.45% at age 11 to nearly peak levels (-0.05%) at age 17. Grip strength then stabilized between ages 18 and 40, fluctuating slightly above peak values. By age 40, it began to decline (-3.76%), signaling the onset of age-related muscle loss. The rate of decline steepened beyond age 50, dropping to -13.17% by age 60. By age 70, grip strength was 23.13% lower than peak and beyond age 70 it deteriorated more rapidly, reaching -37.48% by age 85-more than a one-third decline from its peak (Table 2).

In males, grip strength in early childhood (ages 3-10) was markedly lower than peak adult strength, with percentage differences from -92.05% at age 3 to -60.06% at age 10. Between the ages of 11 and 17, it increased sharply, reducing deficits from -54.78% at age 11 to -4.35% at age 17. They then peaked between ages 18 and 37, with percentage changes that fluctuated close to zero. Small variations occurred-grip strength rose slightly above peak levels (+0.75% at age 19, +0.63% at age 30) but stabilized around ±1% from ages 18 to 37. After the age of 37 it began to decline, dropping to -1.24% at age 37, -3.24% at age 42 and -7.22% at age 50. The decline accelerated after the age 50, with strength 15.05% below peak by age 62 and 21.28% lower by age 70. Beyond age 70 it continued to fall rapidly, reaching -33.17% by age 85-a one-third reduction from its peak (Table 3).

Nondominant Hand

The percentage change pattern for the nondominant hand closely mirrored that of the dominant hand, exhibiting a similar lifespan trajectory of strength gain and decline. In males, grip strength increased rapidly from -92.13% at age 3 to -5.17% at age 17, reached peak levels between ages 18 and 37 with minor fluctuations (-0.98% to +1.64%), then began to decline after age 37-accelerating from -1.25% at age 40 to -5.87% at age 50-and had decreased by approximately 33% from its peak by age 85. In females, grip strength followed a similar pattern: it improved from -87.75% at age 3 to +1.46% at age 17, peaked between ages 18 and 40 with small variations around +6.05% at age 40, then started to decline after age 40, experienced gradual midlife loss and an accelerated drop after age 60, ultimately resulting in a roughly 33.57% reduction by age 85.

Discussion

This study quantified the rate of change (kg/year) and percentage change (%) in grip strength across the lifespan (ages 3-85), stratified by gender and hand dominance. By leveraging data from the NIH Toolbox, which recruited participants spanning a broad age range, this study provided a comprehensive analysis of grip strength development and decline over time.

While previous studies have examined grip strength decline using longitudinal follow-up (repeated measurement), regression approach or Latent Growth Model (LGM), this study used a smoothing method to estimate the rate of change [31,36-39]. Compared to prior research with larger sample sizes and varying age ranges: 4,728 (ages 18-102), 5,108 (ages 65-90), 48,070 (ages 50-80), this study had a relatively smaller sample size given its broad age range [31,37,39]. However, the NIH Toolbox implemented a purposeful sampling strategy and measured grip strength in both dominant and nondominant hands, providing a more comprehensive assessment of grip strength across the lifespan.

This study supported emerging evidence that grip strength does not decline at a constant rate but rather accelerates with age. Huebner examined grip strength loss per decade in a European cohort (ages 50-80) and reported declines of 3.5 kg in men and 2.3 kg in women from ages 50 to 60 and these declines increased to 6.5 kg and 4.1 kg, respectively, from ages 70 to 80 [39]. Similarly, Yu, found that across a broad age range (18-102 years), grip strength declined progressively, from -0.7% per decade (ages 30-39) to -20.4% (ages 80+) in men and from -1.1% to -15.5% in women [31]. These studies indicated that grip strength does not decline linearly throughout adulthood and old age but rather varies by age [31,36-39].

A key strength of the NIH Toolbox dataset is its oversampling of children aged 3-17 years, allowing for a detailed characterization of rapid musculoskeletal growth during early life and adolescence. This approach ensures a robust examination of age-related grip strength trajectories, capturing peak strength attainment in early adulthood, stability in midlife and progressive decline in later years. The inclusion of individuals up to age 85 further enables an in-depth evaluation of age-related muscle loss, helping to identify critical periods of decline and potential intervention windows to mitigate strength deterioration.

Males vs. females: The change-rate and percentage-change trajectories in grip strength across the lifespan were similar between males and females. Males exhibited a higher growth rate in adolescence (~4-5 kg/year) compared to females (~2-3 kg/year), sustained peak strength slightly longer and initially declined more quickly (Table 2 and 3). Both sexes showed accelerated muscle decline after age 50.

Dominant vs. Nondominant Hand: The rate-of-change trajectories for dominant and nondominant hands in both males and females were generally similar. The dominant hand generally had a slightly higher peak growth rate in adolescence and a more stable plateau in adulthood. While the overall pattern mirrored that of the dominant hand, the nondominant hand showed slightly greater variation in peak levels and a marginally slower initial decline. However, both hands experienced accelerated loss after age 50, emphasizing the impact of aging on muscle strength regardless of hand dominance.

The rate of change in grip strength across the lifespan offers valuable insights for early detection of muscular deficits and timely interventions to maintain physical function. Comprehensive reference data on both absolute and percentage changes across the lifespan provides clinicians with precise benchmarks for evaluating muscle health and resilience, enabling accurate risk stratification at various ages. Grip strength assessments in pediatric check-ups can help track muscle development and identify potential growth delays. Quantifying grip strength changes across the lifespan helps pinpoint when peak strength is attained and when decline begins, offering insights into optimal intervention windows. Monitoring grip strength trends allows for the early identification of muscular decline in high-risk populations, such as those with sedentary lifestyles, chronic diseases (e.g., diabetes, cardiovascular disease) or nutritional deficiencies. Additionally, tracking grip strength loss can help guide preventive interventions against frailty, promoting long-term muscle health and functional independence.

This study had several limitations. First, as a secondary data analysis, researchers had no control over data collection procedures, which made missing values, data entry errors and inconsistencies due to different collection methods unavoidable. However, the NIH Toolbox had implemented quality assurance and control measures to minimize these issues. Second, grip strength testing had been conducted within a comprehensive test battery, which potentially led to fatigue effects, though the extent of this impact remained uncertain. Third, due to time constraints in the NIH Toolbox norming study, only a single maximal trial had been conducted per hand, rather than the best of three trials, which may have resulted in an underestimation of true maximal grip strength. Lastly, multiple methodologies existed for quantifying grip strength rate of change. It was recommended that future studies compare different approaches (e.g., kg/year,%/year, kg/5-year, kg/10-year) to improve methodological consistency and enhance comparability across studies.

Conclusion

Knowing the reference values for the rate of grip strength decline during normal aging is essential for distinguishing healthy aging from early signs of muscle dysfunction. These values serve as benchmarks to assess whether an individual's decline is within the expected range or indicates a higher risk of frailty, sarcopenia or other age-related conditions.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Consent to Participate

Informed consent was also obtained from each subject who participated in the study.

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Data Availability
Data is available for the journal. Informed consents were not necessary for this paper.

Author's Contribution
The authors contributed equally.

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